RECOMMENDATION ITU-R S.1327

REQUIREMENTS AND SUITABLE BANDS FOR OPERATION OF THE INTER-SATELLITE SERVICE WITHIN THE RANGE 50.2-71 GHz

(Question ITU-R 246/4)

(1997)

The ITU Radiocommunication Assembly,

considering

a) that Resolution 643 of the World Radiocommunication Conference (Geneva, 1995) (WRC-95) instructs the ITU-R to carry out the necessary studies to identify the bands most suitable for the inter-satellite service (ISS) in order to enable the World Radiocommunication Conference (Geneva, 1997) (WRC-97) to make appropriate allocations to that service;

b) that the technical and operational requirements of the ISS in the frequency range 50.2-71 GHz are identified in Annex 2 of this Recommendation;

c) that the networks identified in Annex 2 typically require wide bandwidths, and typically form high data rate trunk links for the space segments of networks;

d) that there is extensive planned use of the ISS in the range 50.2-71 GHz;

e) that there is a potential for unacceptable interference from large numbers of inter-satellite links into the Earth exploration-satellite service (EESS) (passive) in this range;

f) that there are no known existing or currently planned terrestrial or space systems in the current allocations in the range 65-71 GHz;

g) that the absorption characteristics of the atmosphere to radio waves, within the range under consideration, may improve sharing conditions with terrestrial stations of other services;

h) that studies have confirmed that sharing between the ISS and terrestrial services in the band 66-71 GHz is feasible (see Annex 3),

recommends

1 that the bands most suitable for the ISS in the range 50.2-71 GHz include:

– 54.25-58.2 GHz, limited to networks employing geostationary-satellite orbit (GSO) satellites in accordance with Recommendation ITU-R S.1339;
– 59-64 GHz;
– 65-71 GHz;

2 that the allocations to the ISS in this frequency range be contiguous bands of sufficient width to accommodate the unique needs of the ISS.

NOTE 1 – Recommendation ITU-R S.1339 addresses feasibility of sharing between the ISS and spaceborne passive sensors in the frequency range 50-65 GHz.

NOTE 2 – Recommendation ITU-R S.1326 addresses sharing between the fixed-satellite service (FSS) and the ISS in the band 50.4-51.4 GHz.

NOTE 3 – Annex 1 to this Recommendation summarizes the sharing potential of the ISS with other services in the frequency range 50.2-71 GHz.

ANNEX 1

This Annex summarizes potential for the ISS sharing with the following services:

a) Fixed service in the bands 50.2-51.4, 54.25-58.2 and 59-64 GHz

Sharing is feasible in these bands. However, the band 50.2-51.4 GHz may not be of sufficient bandwidth to accommodate ISS requirements.

b) FSS in the band 50.4-51.4 GHz

Studies have shown that sharing between GSO ISS and GSO FSS in this band would be feasible with certain mitigation techniques. However, sharing between other systems, such as GSO and non-GSO FSS sharing with non-GSO ISS may be difficult and requires further study (see Recommendation ITU-R S.1326).

c) Mobile service in the bands 50.2-51.4, 54.25-58.2, 59-64 and 66-71 GHz

Studies have shown that oxygen absorption, as well as antenna discrimination, will attenuate signals to an extent which will allow sharing with these systems.

d) EESS (passive) and space research service (SRS) (passive) in the bands 50.2-50.4 GHz, 51.4-59 GHz, 59-64 GHz, and 64-65 GHz

Studies have shown that there is potential for unacceptable interference from non-GSO systems utilizing the ISS in these bands. Sharing between GSO ISS or Hybrid ISS and EESS (passive) is feasible, and sharing conditions are given in Recommendation ITU-R S.1339. In the band 59-64 GHz, existing non-GSO ISS systems could also cause harmful interference and possibly even damage to EESS (passive) sensors. It is recommended that passive sensors be made aware of the potential for interference from existing systems. It is also noted that there are no requirements for the EESS (passive) or SRS (passive) in the band 64-65 GHz, therefore, this band may be suitable for non-GSO ISS. However, this band is also allocated by footnote to the radio astronomy service (RAS), and no sharing studies have been carried out on the feasibility of the ISS to share with the RAS.

e) Radionavigation service (RNS) in the band 66-71 GHz

Studies have shown that oxygen absorption, as well as antenna discrimination will attenuate signals to an extent which could allow sharing between these systems. Information is required on the RNS service to enable firm conclusions to be drawn.

f) Mobile-satellite service (MSS) in the bands 66-71 GHz

Studies have shown that an interference potential would exist from the ISS into MSS spaceborne receivers for systems with similar orbital heights. However, sharing at similar orbital heights may also be possible if use is made of polarization discrimination. Other potential interference situations exist as the MSS has a bidirectional allocation. Interference between these systems requires further study.

g) Radionavigation-satellite service (RNSS) in the band 66-71 GHz

Studies have shown that an interference potential would exist from the ISS into RNSS spaceborne receivers for systems with similar orbital heights. However, sharing at similar orbital heights may also be possible if use is made of polarization discrimination. Other potential interference situations exist as the RNSS has a bidirectional allocation. Interference between these systems requires further study.

h) SRS and the EESS in the band 65-66 GHz

This band will not be used for spaceborne passive sensing; it is intended to be used for the transmission of data in the space-to-Earth direction. Liaison within the ITU-R revealed that there are no current plans for EESS or SRS systems in the band. Sharing between satellite networks in the EESS (space-to-Earth) and SRS (space-to-Earth), and those of the ISS is not expected to be difficult.

ANNEX 2

Characteristics and requirements of systems planning to use the ISS near 60 GHz

1 This Annex identifies systems operating, or planning to operate, in the ISS near 60 GHz. A distinguishing characteristic of these systems is the requirement for large bandwidths. ISS users typically form high data rate trunk links for the space segments of networks. A typical user of the networks might be a user of the FSS, or the MSS.

The typical user might be serviced by a 2.4 kbit/s voice link, or a 1.544 Mbit/s data link, and there might be as many as 250 000 end voice users on a single 1 Gbit/s inter-satellite link (ISL).

2 Estimated bandwidth requirements for ISS for systems near 60 GHz

In order to estimate the bandwidth required for operation of the GSO ISS, a survey of existing and planned GSO ISS systems was conducted. As of end-1996 there are ten GSO ISS systems planned for operation near 60 GHz, with 74 satellites and up to 178 GSO ISLs. Many of the planned GSO locations are crowded over regions of Europe and the United States of America. There are four proposed non-GSO ISS systems, with close to 1 000 satellites and nearly 8 000 links. Most of these systems are low-Earth orbiting systems.

2.1 Short ISLs (short links)

Short ISLs (system angle of 10° or less) are estimated to require up to 10° of orbital separation from co-frequency GSO ISS systems. Each node in a short link requires up to 2 GHz of bandwidth. With 10° of orbital separation required between each co-frequency short link, and 2° of orbital separation between any two GSO satellites, a factor of 5 is estimated to provide adequate spectrum for GSO ISS short links, for a total of 10 GHz.

2.2 Long ISLs (long links)

For long inter-satellite links (orbital separation greater than 10°), 2° of orbital separation between co-frequency GSO ISS systems is enough to achieve the performance criterion of $C/I \geq 30$ dB. Under these conditions, 4 GHz of spectrum is sufficient for frequency re-use, since at least one GSO ISS system is designed for a minimum of 4 GHz. However, there is no guarantee that 2° orbital separations can be maintained, especially in the crowded areas of the geostationary arc. A separation of 1° between systems would imply that twice as much spectrum is needed, as much as 8 GHz.

2.3 Growth

The above analysis does not account for the growth of GSO ISS systems. A growth factor of 1.5 can be used to estimate potential growth of the ISS in the near future (10-20 years). Applying the growth factor yields an estimated requirement of 15 GHz for short links, or 12 GHz for long link GSO ISS systems.

2.4 Estimated bandwidth requirements for non-GSO ISS for systems near 60 GHz

The total bandwidth estimated for the proposed non-GSO systems is 8.2 GHz. Allowing for a growth factor of 1.5, the estimated requirement for non-GSO systems is near 12 GHz.

2.5 Summary

Due to the orbital separations required between GSO ISS systems with short inter-satellite links, and to overcrowded conditions in certain regions of the geostationary arc, the estimated requirement for full use of planned and future GSO ISS systems is 15 GHz. For non-GSO systems, about 12 GHz is the estimate.

3 Additional work to be done

These data rates can be associated with the hypothetical digital reference path (HDRP) standards, to allow meaningful sensitivity to interference to be defined.

TABLE 1

GSO system characteristics

GSO systems	W-1	W-2a (1)	W-2b (1)	W-3	W-4	W-5	W-6	W-7	W-8	W-10
No. of satellites	3	4	15	12	17	4	2	2	5	10
No. of Tx/Rx pairs per satellite	2	2	2	2	2-4	2	1	1	2	1
Bandwidth (GHz)	1	3.2	0.04	0.5	1	1	0.12	0.12	1	2.5
Total bandwidth required (GHz)	2	3.2	0.08	1	4	2	0.24	0.24	2	5.0
Peak power (dBW)		16	–1	8.5	8	11.76	13	13	13	21
Peak e.i.r.p. (dBW)	71.3	75	57	54.5/63.5	68.3	64.78	63.3	62.1	68.7	75
Antenna gain (dBi)	58.5	60.3	58	46/55.5	60.3				55.7	53.5
Antenna diameter (m)	1.8	2		0.4/1.2	1.8		0.75	0.75	1	1
System noise temperature (K)	468.4	800	2 034		630		290	290	330	800
Rx G/T (dB(K^{-1}))			24.9	19/28.5		19.8/25.9	23.4	23.4	27.4	24.5
Largest longitudinal separation angle (degrees)	145	163	163	141	163	17	34	24	100	106

(1) Any of the W-2 system nodes can communicate with other W-2 nodes.

TABLE 2

Non-GSO system characteristics

Non-GSO systems	LEOSAT 1	W-2c	W-2d	W-9
Orbital parameters				
No. of planes	21	10	12	12
No. of satellites per plane	44	1	1	6
Period (average) (min)	98.77	718.03	105	113
Inclination (average) (degrees)	98.16	63.4	55-110	47
Ascending node spacing (degrees)	9.5	Various	Various	30
Eccentricity		0.72	Various	0.0013
RF parameters				
No. of Tx/Rx pairs per satellite	8	2	2	4
Bandwidth of each beam (GHz)	1	3.2	3.2	1.5
Total bandwidth required (GHz)	2	3.2	3.2	3
Peak power (dBW)	7.4	16	16	4
Peak e.i.r.p. (dBW)	55.4	75	75	59.9
Antenna gain (dBi)	48	60.3	60.3	55.9
Antenna diameter (m)	0.5	2	2	1.2
System noise temperature (K)	438	800	800	501
Maximum geocentric separation angle (degrees)	19	–	–	30

NOTE 1 – Any of the W-2 system nodes can communicate with other W-2 nodes.

NOTE 2 – Maximum bandwidth cited. Lower bandwidths may also be used.

ANNEX 3

Assessment of potential allocation of the ISS in the 66-71 GHz band

1 Introduction

The ISS has a co-primary allocation in the 54.25-58.2 GHz band which is used by the EESS for passive sensing. Microwave sensors on board operational spacecraft can provide environmental and climatic data which are increasingly important for monitoring the temperature of the Earth's atmosphere. The atmospheric temperature profiles are of fundamental importance for initialization of numerical weather prediction models, and for retrieval of other important scientific data.

The global user community, including the World Meteorological Organization, the Global Climate Observing System and the World Climate Research Programme, have defined satellite data requirements for atmospheric parameters including temperature and water vapour profiles, ozone concentration, and other radiatively and chemically active trace gases, which can only be met by satellite passive sensors. Oxygen absorption lines in the 50.2-66 GHz region are unique natural resources used for all-weather passive microwave remote sensing of the atmosphere. An alternative is not available in other frequency bands.

The frequency band 54.25-58.2 GHz is shared between EESS (passive), fixed, mobile and ISSs. It has been concluded in earlier studies that inter-satellite systems with a significant number of low-Earth orbiting satellites can produce unacceptable levels of interference to passive microwave sensors. The Space Frequency Coordination Group (SFCG) has resolved that it would be very desirable to make the relevant frequency band exclusive for passive services and to re-allocate the ISS in the frequency range 66-71 GHz, except for the 56.9 to 57 GHz band, to ensure the ability to make atmospheric temperature measurements and to avoid a need for constraints on the parameters for active services. The 66-71 GHz band provides 5 GHz of bandwidth compared to 3.95 GHz in the 54.25-58.2 GHz band and should thus be an attractive alternative to the current allocation.

This study concentrates on the sharing assessment between ISS and all primary services allocated in the 66-71 GHz band.

2 ISS system characteristics

It is difficult to make general predictions on characteristics for ISS systems which would use frequencies above 50 GHz. There is, however, one system already in an advanced planning stage which can be used as a representative case for a sharing assessment. The proposed non-GSO type system is referred to as LEOSAT-1 and consists of 924 low-Earth orbiting satellites (840 active satellites and 84 spares) which are planned to provide basic voice services, multimedia conferencing, tele-medicine, distance learning and video telephony on a global basis. The inter-satellite links are designed in such a way that each satellite is connected to the closest four satellites in the same orbit plane and to two others each in the two adjacent planes. Transmissions are planned to be effected at 56 and 59 GHz, left-hand circular and right-hand circular, in order to reduce mutual interference. Typical technical characteristics of a potential future system, for which Appendix 3 to the Radio Regulations information was submitted to the ITU in 1995 are given in Table 3.

Each satellite is connected to eight other satellites so that eight transmissions per satellite have to be considered in total. The links between the various satellites are shown in Fig. 1.

For the purpose of this study, it is assumed that the 56 GHz transmissions can be moved to frequencies around 66 GHz and the 59 GHz transmissions to 70 GHz. Regarding atmospheric attenuation, the 70 GHz case is the more critical one because attenuation due to dry air is significantly higher at 66 GHz and results consequently in lower interference signal levels at the Earth's surface. In order to get an overview of the worst case, the study will concentrate on transmissions around 70 GHz.

TABLE 3

Technical characteristics of a potential ISS system

Parameter	Value
Carrier frequencies (GHz)	56, 59
Power per channel (dBW)	7.4
Maximum antenna gain (dBi)	48
Minimum antenna gain (dBi)	–10
Maximum e.i.r.p. (dBW)	55.4
Antenna pattern	Recommendation ITU-R S.672
Polarization	Left- and right-hand circular
Channel bandwidth (GHz)	1
Maximum data rate per channel (Gbit/s)	1.24416
Maximum power spectral density (dB(W/MHz))	–22.6
Maximum e.i.r.p. density (dB(W/MHz))	25.4
Orbit height (km)	695-705
Eccentricity	0.00118
Inclination (degrees)	98.2
Right ascension angle (degrees)	$n \times 9.5$ ($n = 0$ to 20)
Number of orbital planes	21
Inter-plane spacing (degrees)	9.5
Intra-plane satellite spacing (degrees)	9
Number of satellites per plane	40 (44)
Orbital period (min)	98.8

The re-allocation of the links requires some minor design modifications. In order to achieve the same link performance at 70 GHz as compared to 59 GHz, 1.5 dB differential space loss must be compensated. This can be achieved by slightly increasing the antenna gain on the receiving as well as on the transmitting satellite. It is assumed that a maximum antenna gain of 49 dBi instead of 48 dBi is sufficient. The wavelength at 70 GHz is 4.3 mm.

From the above data, the diameter of the antenna and the half power beamwidth can be calculated. Assuming an efficiency of 60%, the diameter of a parabolic antenna with 49 dBi gain is approximately 0.5 m at 70 GHz. This results in a one-sided half power beamwidth of 0.31° (3 dB beamwidth). The following equations have been used to derive the above parameters:

$$G_m = 10 \log (110 \, \eta \, D^2 \, f^2) \tag{1}$$

$$\theta_3 = 36.4 \; (\lambda / D) \qquad (\text{one-sided}) \tag{2}$$

where:

G_m: maximum antenna gain

η: efficiency

D: antenna diameter (m)

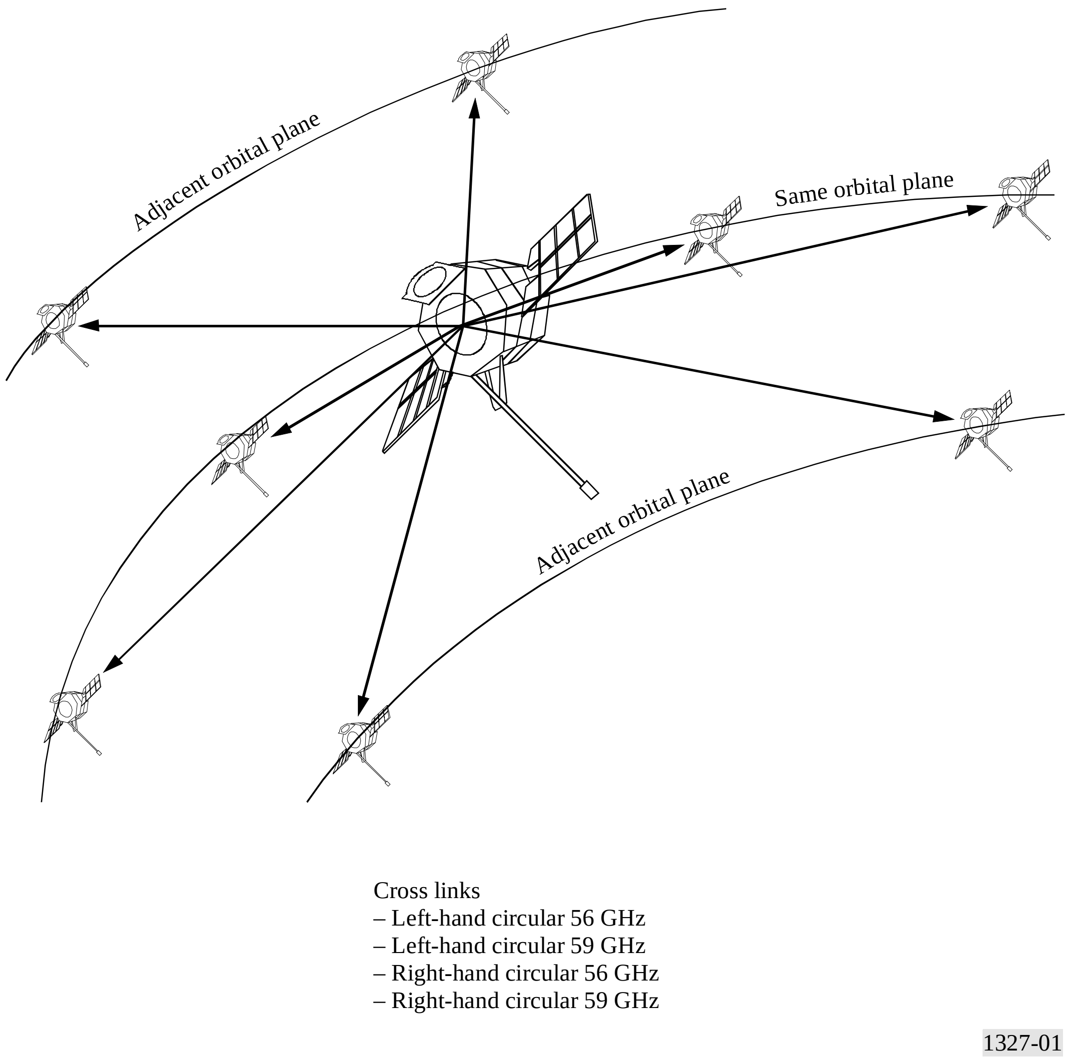
f: frequency (GHz)

θ_3: half power (3 dB) beamwidth (one-sided)

λ: wavelength.

FIGURE 1

Cross-link constellation



The antenna reference pattern is of major significance for the calculation of the antenna gain roll-off and consequently the power flux-density (pfd) distribution. The pattern considered to be most representative is contained in Recommendation ITU-R S.672 and is characterized by the following equations:

$$G = \begin{cases} G_m - 3\,(\theta/\theta_3)^2 & \text{for} \quad \theta \le 2.6\,\theta_3 & (3) \\ G_m - 20 & \text{for} \quad 2.6\,\theta_3 < \theta \le 6.3\,\theta_3 & (4) \\ G_m - 25\log(\theta/\theta_3) & \text{for} \quad \theta > 6.3\,\theta_3 & (5) \end{cases}$$

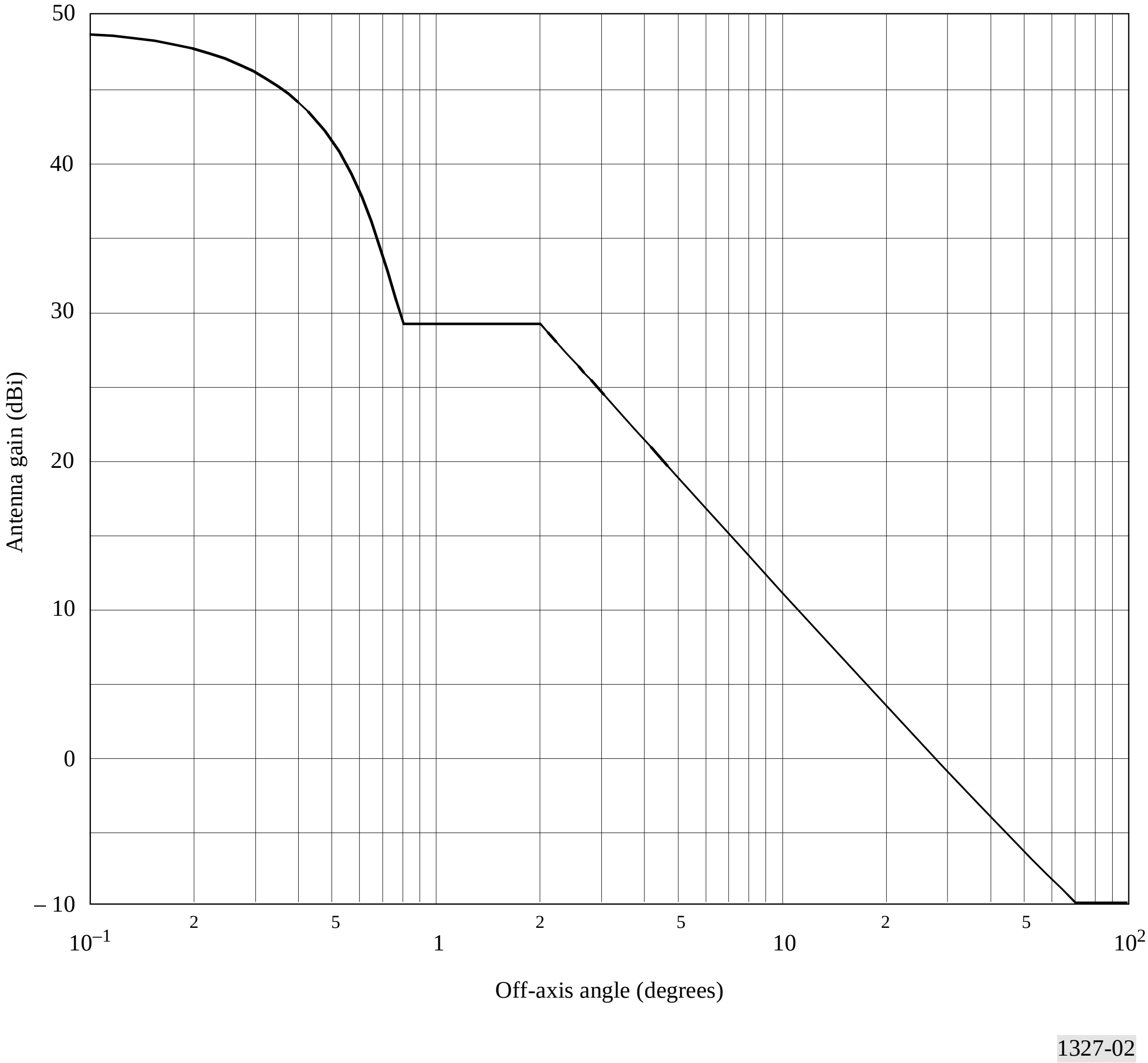
Figure 2 shows the antenna gain reference pattern for a 0.5 m antenna at 70 GHz. A minimum gain of –10 dBi has been introduced in agreement with the system specifications.

3 Protection requirements of affected services

The 66-71 GHz band is currently allocated on a primary basis to the mobile, the mobile-satellite, the radionavigation and the radio navigation-satellite services. No direction indicators are given for the two satellite services which suggest that the bands have not even been considered for applications yet. Protection requirements are not specified in any ITU documentation so that some assumptions on proper protection have to be made.

FIGURE 2

Antenna gain contour for cross links



Terrestrial services and space-to-Earth links can in general be protected by adequate pfd limits applicable at the Earth's surface. Such a pfd limit would presumably be applicable to either or both of the two satellite services if they operate in the space-to-Earth direction. It may consequently be appropriate to identify a suitable pfd limit for an ISS operating in the 66-71 GHz band.

The Radio Regulations do not specify pfd limits above 40.5 GHz. The nearest values for consideration are consequently the following limits applicable in the 31 to 40.5 GHz band:

-115 dB(W/m^2):	in any 1 MHz band for angles of arrival between 0° and 5° above the horizontal plane
$-115 + 0.5(\theta - 5)$ dB(W/m^2):	in any 1 MHz band for angles of arrival between 5° and 25° above the horizontal plane
-105 dB(W/m^2):	in any 1 MHz band for angles of arrival between 25° and 90° above the horizontal plane.

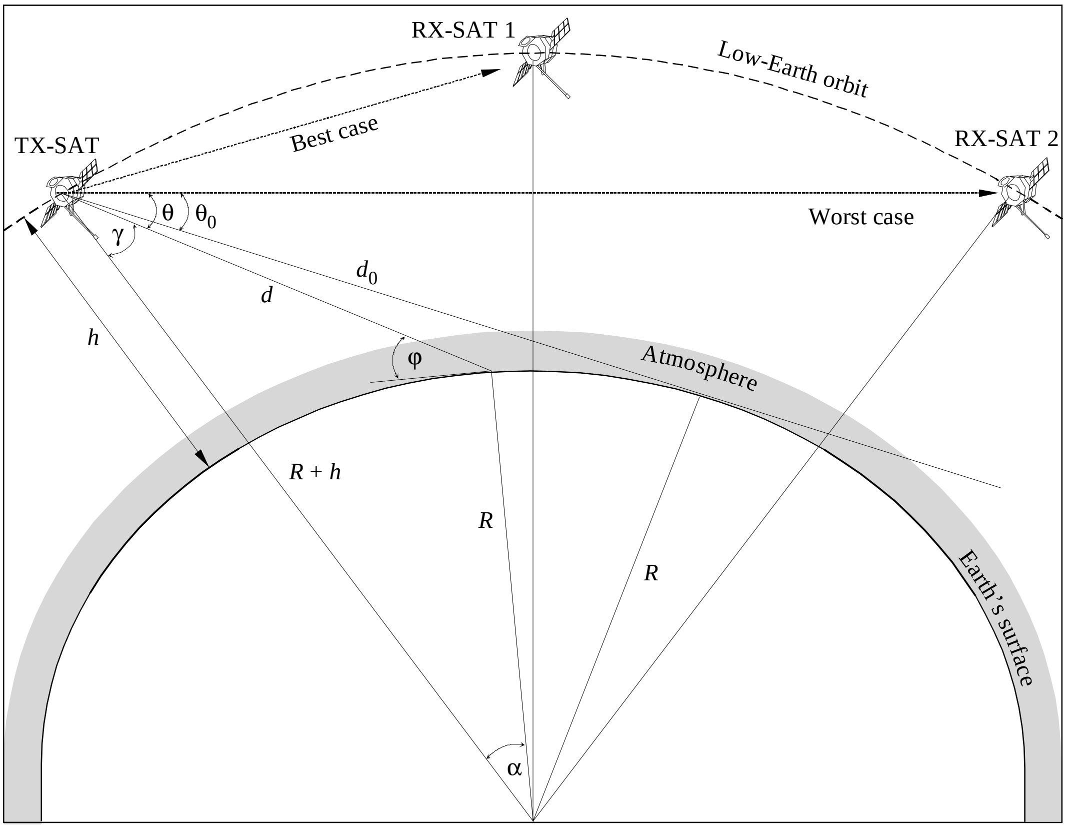
4 Sharing assessment

Figure 1 shows the various constellations for cross-link transmissions. For short-distance links, the antenna roll-off angle with respect to the surface of the Earth is higher than for longer distance links. In addition, power levels could also be reduced for short distance transmissions.

The following two constellations shown in Fig. 3 represent the worst and the best case for the calculation of pfd on the Earth's surface. For the worst case, satellite TX-SAT transmits a signal to the most distant satellite RX-SAT-2. The transmission angle is closer to the Earth then in the case of a transmission to the intra-plane RX-SAT-1. The constellation for transmissions to satellites in adjacent planes varies but is in any case expected to be less critical compared to the worst case of the intra-plane constellation. In some specific constellations close to the poles, the distances may even be lower than the shortest one in the intra-plane cases. The geometrical constellations are straightforward and illustrated in Fig. 3. The drawing is not to scale in order to improve its clarity.

FIGURE 3

Geometrical relationships for pfd calculations



Note 1 - Drawing not to scale.

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The calculation of pfd levels on the surface of the Earth would be relatively simple if no atmospheric attenuation has to be taken into account. Main factors determining the pfd levels are the power spectral density, the resulting antenna gain towards the surface of the Earth and the distance to the point of impact. At high frequencies, however, atmospheric attenuation due to dry air (mainly oxygen) and water vapour cannot be neglected.

The pfd at the Earth's surface can be calculated according to:

$$pfd = PSD + G - 10 \log (4 \pi d^2) - A_a \tag{6}$$

where:

PSD: maximum power spectral density

G: antenna gain contour

d: distance to Earth's surface

A_a: atmospheric attenuation.

Recommendation ITU-R P.676 lists the applicable equations for the impact of dry air and water vapour. The specific attenuation γ_o due to dry air for a pressure of 1 013 hPa and a temperature of 15° C is given by:

$$\gamma_o = \left[0.00719 + \frac{6.09}{f^2 + 0.227} + \frac{4.81}{(f - 57)^2 + 1.5}\right] f^2 \times 10^{-3} \quad \text{dB/km} \tag{7}$$

For a frequency around 70 GHz, the value of $\gamma_o = 0.18$ dB/km. This value is already significantly lower than the maximum attenuation which can be found at 60 GHz which is more than 10 dB/km. The specific attenuation γ_w due to water vapour for a pressure of 1 013 hPa and a temperature of 15° C is given by:

$$\gamma_w = \left[0.05 + 0.0021\,\rho + \frac{3.6}{(f - 22.2)^2 + 8.5} + \frac{10.6}{(f - 183.3)^2 + 9.0} + \frac{8.9}{(f - 325.4)^2 + 26.3}\right] f^2 \rho \times 10^{-4} \quad \text{dB/km} \tag{8}$$

For a typical water vapour density of $\rho = 7.5$ g/m^3 and a frequency around 70 GHz, the value of $\gamma_w = 0.25$ dB/km.

It is apparent that the attenuation decreases with increasing height above the Earth's surface. The height of the receiving terminal which is interfered with has therefore to be taken into account. In order to calculate the attenuation along the transmission path for a specific elevation angle, the following equations can be used:

$$A_a = \frac{h_o \gamma_o e^{-h_s/h_o} + h_w \gamma_w}{\sin \varphi} \quad \text{dB} \qquad \text{for } 10° < \varphi \le 90°$$

$$A_a = \frac{\sqrt{R_e}}{\cos \varphi}\left[\sqrt{h_o}\ \gamma_o\ \mathrm{F}(x_1)\, e^{-h_s/h_o} + \sqrt{h_w}\ \gamma_w\ \mathrm{F}(x_2)\right] \quad \text{dB} \qquad \text{for } 0° < \varphi \le 10° \tag{9}$$

$$\mathrm{F}(x_i) = \frac{1}{0.661 x_i + 0.339\sqrt{x_i^2 + 5.51}} \qquad \text{for } i = 1, 2 \tag{10}$$

$$x_1 = \cos \varphi \left[\sin \varphi \ \tan^2 \varphi \sqrt{\frac{R_e}{h_o}} + \sqrt{\frac{R_e}{h_o} + 2\frac{h_i}{h_o} + \frac{h_i^2}{2 R_e h_o}}\right] \tag{11}$$

$$x_2 = \cos \varphi \left[\sin \varphi \ \tan^2 \varphi \sqrt{\frac{R_e}{h_w}} + \sqrt{\frac{R_e}{h_w} + 2\frac{h_i}{h_w} + \frac{h_i^2}{2 R_e h_w}}\right] \tag{12}$$

$$h_w = h_{w0}\left[1 + \frac{3.0}{(f - 22.2)^2 + 5} + \frac{5.0}{(f - 183.3)^2 + 6} + \frac{2.5}{(f - 325.4)^2 + 4}\right] \quad \text{km} \tag{13}$$

where:

- h_o: equivalent height for dry air (6 km)
- h_w: equivalent height for water vapour
- h_{w0}: 1.6 in clear weather, 2.1 in rain (km)
- R_e: effective Earth radius including refraction (8 500 km)
- φ: elevation angle.

A computer program has been developed which calculates the pfd levels at the surface of the Earth as a function of all above factors for elevation angles between 0° and 90°. The program has been written in a way to allow testing of the sensitivity of the results versus any of the input parameters. A representative “bad” case has been selected based on a number of pessimistic assumptions. Figure 4 shows a comparison of the individual attenuation factors.

FIGURE 4

Pfd attenuating components

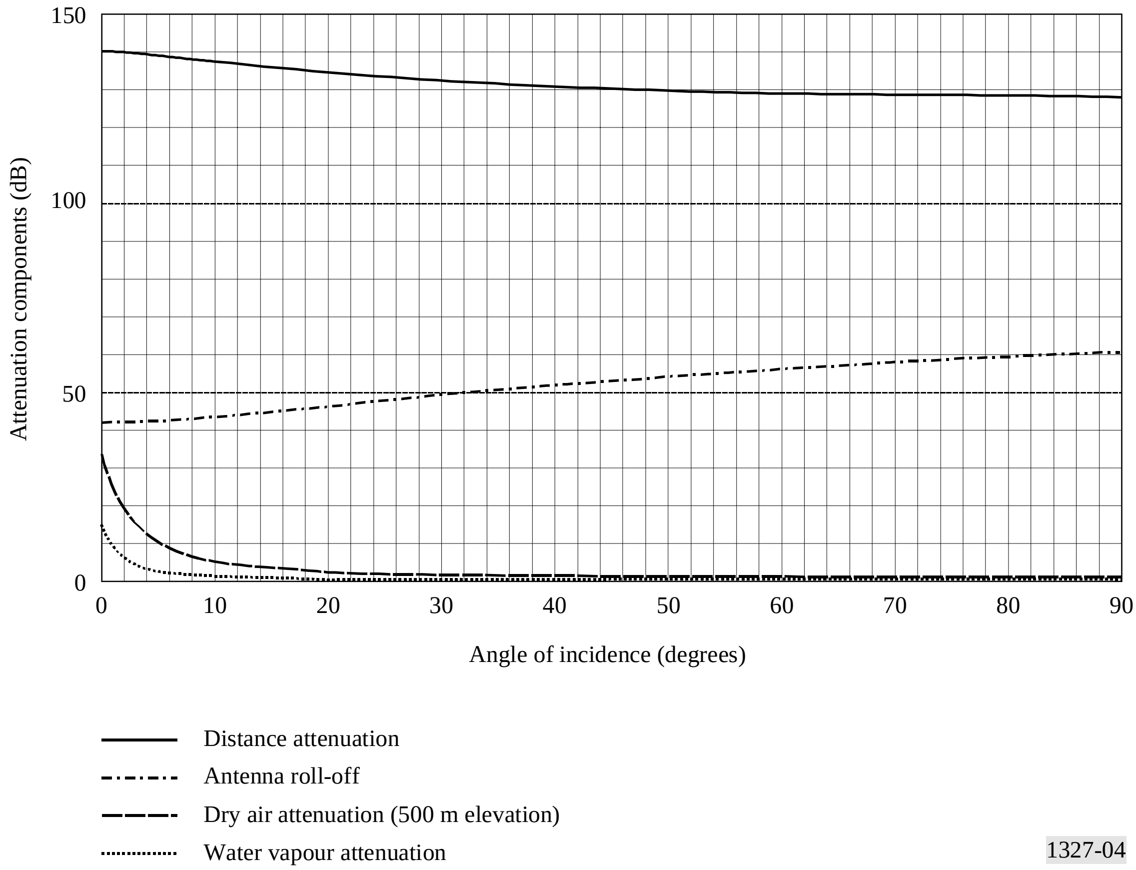
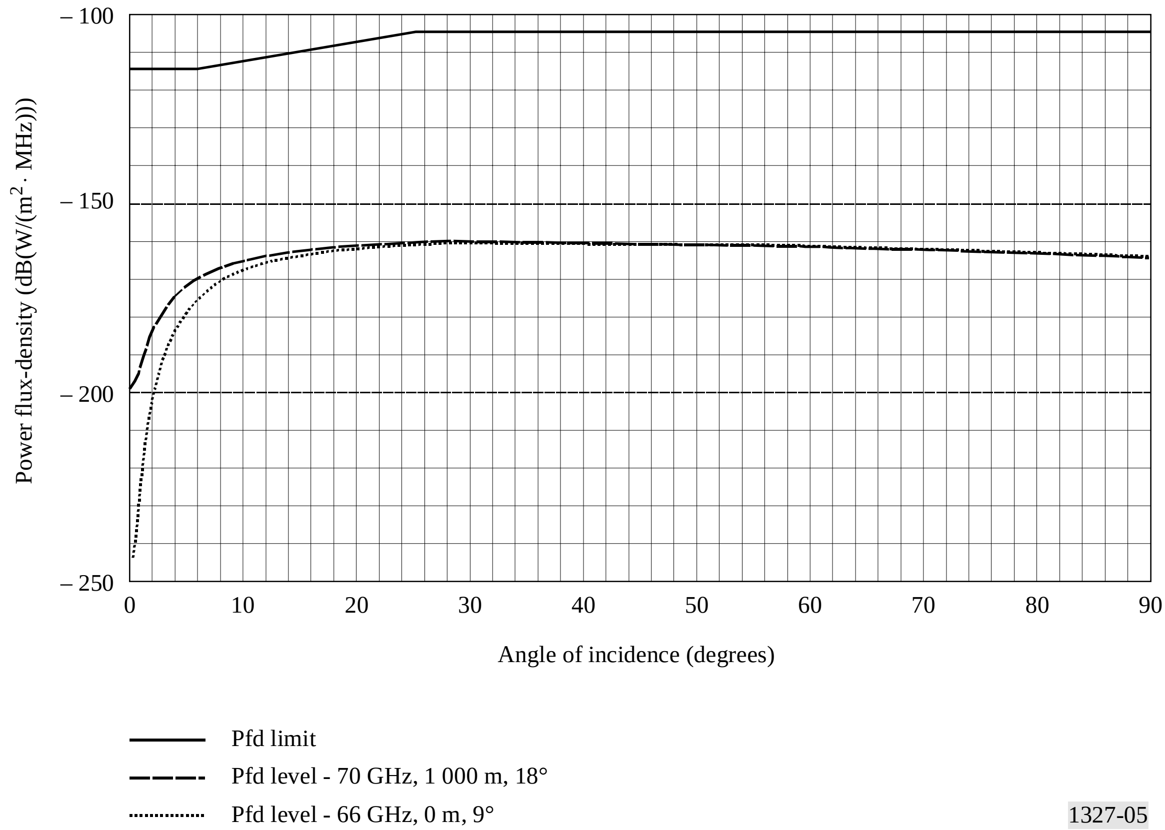


Figure 5 shows the pfd results for the most adverse and the most favourable intra-plane constellation assuming elevations of 1 000 m and sea level, and 70 and 66 GHz, respectively, a temperature of 15° C, and a water vapour density of 7.5 g/m^3. It can be seen that pfd levels produced at the surface of the Earth are more than 50 dB below a potential pfd limit as specified for the nearest band around 40 GHz.

A single LEOSAT 1 satellite would under no circumstances come close to any potential pfd limits. However, a large number of satellites may be transmitting simultaneously. Of interest is consequently the cumulative effect of the ISS system as a whole. An upper bound for this cumulative effect can be derived by taking into account the surface illuminated by one satellite and extrapolating it to the total number of satellites in the system. A low-Earth orbiting satellite at 700 km orbit height illuminates approximately 5% of the Earth’s surface if angles of incidence down to 0° are taken into account. Consequently, 840 active satellites, equally spaced around the globe, with four links on each transmission frequency, have a cumulative effect to the extent that the average pfd level is increased by approximately 22 dB. This assumption does not take into account the different polarization planes. In addition, the assumption of constant pfd levels down to an angle of incidence of 0° is very pessimistic, as the pfd levels are rapidly decreasing below approximately 10°.

FIGURE 5

Pfd contour versus pfd limit



So far, only interference from the ISS to other services has been considered. There could also be cases where interference is caused to the ISS by the other services sharing the band. The following brief assessment can be made:

Mobile and radionavigation:

Transmissions will generally occur along the Earth's surface. Dry air and water vapour attenuation (see Fig. 4) as well as antenna discrimination will attenuate the signals to an extent which will definitely not result in any harmful interference levels.

Mobile-satellite and radionavigation-satellite:

An interference potential would exist for systems with similar orbital heights as the ISS system. However, even in such a case, a band could still be shared if transmissions are effected on opposite polarizations. This is due to the narrow beam antennas employed which offer a high polarization discrimination.

5 Conclusions

Sharing between any terrestrial service and the ISS in the frequency band 66-71 GHz is clearly feasible because of narrow-beam antennas and atmospheric effects. The same conclusion applies to satellite systems operating in the space-to-Earth direction. The pfd's produced by a single ISS satellite are expected to be 50 to 80 dB below pfd limits currently specified for the 40 GHz region. Even the cumulative effect of a very large number of satellites will only raise the cumulative pfd levels between approximately 10 and 20 dB and thus remain significantly below reasonable pfd limits.